

specific absorption rate (SAR) distribution. The measurement data is obtained with a saline phantom consisting of a tube with elliptical cross section. The tube is inserted into the BSD-2000/3D Sigma60 and a probe inside is moved in 3 spatial dimensions. The probe, a commercial isotropic SAR sensor, is scanned in 2 cm steps for a distance of 20 cm in horizontal and vertical directions and relative SAR values are recorded. Planned and measured data in the central plane of the applicator are compared for the location of the focus to assess the transferability of treatment plans to the treatment machine.

**Results:** The location of the focus maximum can be determined from the graphs and compared to the location of the maximum from the simulation. For the investigated plans an agreement between simulation and measurement was found with deviations of the focal area between 0 and 2 cm.

**Conclusion:** Good agreement for the investigated patient plans was found between simulation and measurement. With an automated measurement system higher resolutions and 2D or 3D comparisons would be possible. The method described allows the transferability of a patient treatment plan to the treatment machine to be verified, however it does not check the correct heating of the patient.

#### EP-1939

An optimal grid block design for spatially fractionated radiation therapy

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**Purpose or Objective:** In the present work, we performed model calculations of cell survival to design a Grid block with optimal therapeutic ratio. The optimal Grid block was manufactured and dosimetric characteristics of the Grid were introduced.

**Material and Methods:** The Geant4 toolkit (Version 9.6.p02) was used to simulate the head of the Varian2100C linear accelerator for a 6 MV photon beam based on the vendor detailed information. The dose distributions of a Grid block with hole-diameters of 0.5 cm, 0.75 cm, 1.0 cm, 1.25 cm, and 1.5 cm with constant center-to-center spacing of 1.8 cm, were calculated separately using the Monte Carlo simulation technique. A dose profile from Monte Carlo simulation, across a single hole of the Grid, has been utilized to calculate therapeutic ratio for different Grid blocks separately. The Hug-Kellerer (H-K) radiobiological model (Equation 1) which is more appropriate at doses higher than 12 Gy was utilized to calculate survival fraction of cell lines under a single hole of the Grid. The values of  $\alpha/\beta$  ratios for tumor cells and normal cells were considered to be 10 Gy and 2.5 Gy, respectively.

Equation 1:

$$\left\{ \begin{array}{l} SF = \sum V_i e^{(-k_1 D_i + k_2 (1 - \exp(-k_3 D_i)))} \\ \alpha = k_1 - k_2 \cdot k_3 \quad \beta = k_2 \cdot k_3^2 \cdot (\ln(2) - 1/2) / (\ln(2))^2 \end{array} \right.$$

Where the  $V_i$  represents the relative cell numbers receiving the same dose ranging from  $D_i$  and  $D_{i+1}$ . The therapeutic advantage of the Grid irradiation was considered in terms of the normal tissue cell survival ratio (Grid/open field ratio) for the same tumor cell survival.

A Grid with optimal TR value was selected to manufacture. Dosimetric characteristics of the Grid were measured using ionization chamber in water phantom and Gafchromic film dosimeter in Solid Water™ phantom materials.

**Results:** The results from the Monte Carlo studies showed that increasing the spacing between the Grid holes with a given hole diameter keep the TR value of the Grid block nearly unchanged ( $\pm 4\%$ ). Moreover, a Grid block with a hole-diameter of 1.0 cm and 1.25 cm may lead to about 19% higher clinical responses relative to the Grids with hole-diameters smaller than 1.0 cm or larger than 1.25 cm. Dosimetric measurements of the optimal Grid were in good agreement ( $\pm 5\%$ ) using different dosimetry techniques. Table 1 shows comparison between different dosimetric features of the manufactured Grid and the dosimetric features that were predicted by Monte Carlo simulation.

Table 1

	Geant4-Monte Carlo simulation	Ionization chamber dosimetry	Film dosimetry	Max difference
Output factor	0.87	0.85	0.83	-4.6%
Valley-to-Peak ratio	21%	20.4 %	19.8 %	-5.7%
TR (15 Gy to dmax)	1.95	2.00	1.87	-4.1 %
EUD (15 Gy to dmax)	6.14	6.3	6.0	-2.6%

**Conclusion:** Designed Grid block leads to have an optimal therapeutic ratio for spatially fractionated radiation therapy.

#### EP-1940

Individual cases review in KROG-0806 study Phase III randomized trial for breast cancer patients

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**Purpose or Objective:** Korea Radiation Oncology Group (KROG)-0806 study has been the phase III randomized trial to investigate the efficacy of internal mammary node (IMN) irradiation in breast cancer patients. Previous dummy run study evaluated protocol compliance of participating institutions. The purpose of this study is to assess the protocol compliance based on individual cases review (ICR).

**Material and Methods:** For ICR, patients were divided into eight subgroups based on IMN irradiation (non-irradiation (N) vs. Irradiation (R)), tumor laterality (left-side (L) vs. right-side (R)) and type of surgery (breast-conserving surgery (B) vs. mastectomy (M)), respectively: NLB, NRB, NLM, NRM, RLB, RRB, RLM and RRM. We extracted 15% among patients enrolled in each subgroup using the SURVEYSELECT procedure with the simple random sample. Then, all participating institutions were requested to upload the following information: planning computed tomography (CT) images, structure sets, and radiation doses as well as the documents containing treatment techniques and all beams' eye views with questionnaire. We performed the comparison of the dose distribution among 8 subgroups. Major and minor violations are determined according to IMN treatment and dose delivered to IMN.

**Results:** The information of 102 patients was collected. Institutions used the different treatment techniques such as standard tangents (42.2%), partial wide tangent (23.5%), 30/70 photon/electron mix (17.6%), IMN-electron only (4.9%), and reverse hockey stick (11.8%). The IMN average doses in subgroups were as follows: Arm1[NLB(14.9Gy $\pm$ 10.7Gy), NRB(18.5Gy $\pm$ 13.0Gy), NLM(27.7Gy $\pm$ 16.4Gy), NRM(27.5Gy $\pm$ 15.1Gy)] and Arm2[RLB(48.3Gy $\pm$ 4.5Gy), RRB(50.9Gy $\pm$ 4.1Gy), RLM(49.3Gy $\pm$ 4.1Gy), RRM(51.3Gy $\pm$ 3.2Gy)]. The dose differences between Arm1 and Arm2 groups were statistically significant. Dose variations in IMN were much greater in Arm1 than Arm2. In Arm1 group,

major violation was found as 7 out of 51 cases. By contrast, there were no major violation and one minor violation in Arm2.

**Conclusion:** This ICR study with KROG-0806 showed the satisfactory protocol compliance in IMN irradiation and the major violation from several cases of IMN non-irradiation group. Quality assurance process using ICR is needed to evaluate and improve the quality of clinical trial in the field of radiation oncology.

#### EP-1941

Assessment of variation in planning benchmark case for ABC-07 trial of liver SBRT

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#### Purpose or Objective

Quality assurance of radiotherapy clinical trials ensures protocol compliance and robustness of outcome data. Benchmark cases are used to assess consistency of outlining and planning by different centres, and provide feedback before a centre starts recruitment. For a complex technique such as liver SBRT, it also facilitates sharing of best practice and supports centres with less experience.

**Material and Methods:** The planning benchmark case was a large (6cm) cholangiocarcinoma with target and organ-at-risk contours already outlined. This case was sent to all centres interested in joining the ABC-07 multicentre phase II trial (Addition of stereotactic body radiotherapy to systemic chemotherapy in locally advanced biliary tract cancers; CRUK A18752; Sponsor University College London). Centres were asked to produce a plan with prescription dose of 50Gy in 5 fractions, having PTV coverage D95% > 95% (optimal, 90% mandatory) and mean liver dose < 13Gy. If this was not possible, the prescription dose was reduced to 45Gy in 5 fractions and mean liver dose limit increased to 15Gy.

**Results:** 14 cases were submitted, covering a range of planning systems and treatment platforms. 5/10 VMAT, 1/1 IMRT and 0/3 Cyberknife plans were able to cover 95% of the PTV with ≥90% of 50Gy, whilst maintaining the mean liver dose below 13Gy, as shown in the table.

Modality (prescription dose)	Number of centres	D95% (% of 50 Gy)	Max (D0.1cc) (% of PD)	Mean liver dose
VMAT (50Gy)	5	44.9 - 48.2 Gy (90 - 96%)	103 - 117%	12.7 - 12.9 Gy
IMRT (50Gy)	1	48.2 Gy (96%)	106%	12.8 Gy
VMAT (45Gy)	5	42.6 - 45.0 Gy	103 - 126%	12.9 - 14.9 Gy
Cyberknife (45Gy)	3	42.7 - 44.9 Gy	114 - 129%	14.6 - 15.0 Gy

**Conclusion:** Achieving the planning objectives for this case was challenging and only 5/12 centres submitted an optimal plan. The other 7 centres are repeating the exercise after feedback on what was achievable with similar equipment. Achieving the optimal plan for this case involved reduced conformity of medium doses in order to spare other parts of the liver, and thereby reducing the total mean liver dose. This approach is contrary to typical Cyberknife planning, so it may not be the optimum treatment platform for these cases, although it is possible that differences between technologies and centres were accentuated by this large and challenging case, and may be reduced for smaller lesions. All patients treated within this trial will be prospectively reviewed, which will further inform this question.

#### EP-1942

Initial experience with the Elekta Leksell Gamma Knife Icon system: commissioning, QA and workflow

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**Purpose or Objective:** Icon enables fractionated stereotactic radiotherapy using a frameless patient positioning system (PPS). For submillimetre precision, the planning MRI scans are registered to a CBCT scan set acquired using Icon. Patient position is then adjusted using the Icon scan. Movement is monitored using an Intra Fraction Motion Management (IFMM) system.

This presentation reports on the commissioning of Icon plus baseline and ongoing QA measurements.

This is the first use of Icon in the UK.

**Material and Methods:** CTDI was assessed for both the low and high dose settings and image quality checked using CatPhan. kVp measurements were made and dose to the imager assessed to confirm the Elekta presets and baseline values.

A new Focus Precision Check tool containing diodes and ball bearings was used to ensure the accuracy of the PPS relative to the radiation focus and CBCT image positions.

The IFMM system was verified using a moveable phantom. A reflector was attached to the phantom and moved independently in the x,y and z directions in 0.5 mm steps.

If the IFMM monitored position is outside tolerance for more than 2 seconds, the treatment pauses and the couch is retracted. Treatment resumes following a re-scan, with the plan recalculated on the new CBCT reference. To test this system an output measurement was interrupted using a remotely moved reflector.

An end-to-end check on a fractionated pituitary plan was made. The plan was recalculated on a CBCT scan of the spherical solid water phantom containing inserts for chamber and film. A film was positioned at the central axis with 2 additional films displaced 5 & 10 mm above and below.

**Results:** The Icon system performed within specification. Patient doses were acceptable and image quality resulted in good registration with the MRI scan sets.

Ongoing QA results were highly reproducible demonstrating positioning ability of the system to within 0.5 mm. The IFMM readout agreed with the independent system to within 0.04mm and repositioning following interruption had no significant effect on the diode doserate. The end to end film dosimetry agreed to within ±3% of the planned dose.

The Icon system has allowed us to use new clinical pathways with little loss in positional accuracy including:

- Single fraction patients who would not tolerate a fixed frame.
- Fixed frame patients who have their CT scan with Icon.
- Fractionated patients.

**Conclusion:** Icon is an efficient system which has enabled the delivery of fractionated stereotactic radiotherapy plus improvements for single fraction patients. Accuracy is comparable with fixed frame treatments.

#### EP-1943

Implications of gold nanoparticles used for dose enhancement in proton radiotherapy

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**Purpose or Objective:** Heavy metal nanoparticles (NPs) have been widely investigated within x-ray radiotherapy as radiosensitisers, where gold NPs (GNPs) have been deemed to be effective at enhancing the dose to the tumour. Few studies have been carried out for protons, where an extensive investigation of the enhancing factors needs to be carried out to determine the implications that introducing GNPs can have on known dose profiles. In the present work, we demonstrate our model which uses Geant4 to carry out Monte Carlo simulations of NP concentrations being irradiated by a proton beam. These simulations offer an indication as to